UM10797

SSL5015DB1201 120 V 18 W low THD low ripple dual stage converter

Rev. 1 — 28 May 2014 **User manual**

Document information

Info	Content
Keywords	SSL5015DB1201, non-dimmable, LED driver, boost buck dual stage converter, TLED, Low Total Harmonic Distortion (LTHD), Low Ripple (LR)
Abstract	This document describes the operation of a 120 V 18 W non-dimmable LED driver featuring the SSL5015 using a boost/buck dual stage topology. The SSL5015DB1201 demo board has a form factor that is compatible with the base of a T8 LED lamp fitting used in Solid State Lighting (SSL) applications

Revision history

Rev	Date	Description
v.1	20140528	first issue

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1. Introduction

WARNING

Lethal voltage and fire ignition hazard

The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

This document describes the operation of a 120 V 18 W non-dimmable LED driver featuring the SSL5015. The SSL5015DB1201 demo board has a form factor that is T8 LED lamp compatible. The boost buck dual stage converter topology provides a simple and efficient solution that achieves low input THD and low output ripple with a small output buffer capacitor.

The total input power (VA) of the board is 18.6 W at 120 V/155 mA. The demo board is designed to drive an LED load, delivering an output power of 15.6 W at 60 V/260 mA.

The power factor (PF) is 0.96 which gives an actual input power of 0.96×18.6 W = 17.86 W. The resulting efficiency is > 87 %.

The demo board complies with EMI and safety regulations.

Figure 2 shows the SSL5015DB1201 demo board dimensions. The design and the components used ensure that the board fits into a T8 lamp base.

2. Safety warning

The SSL5015DB1201 demo board input is connected to the 120 V mains. Avoid touching the board while it is connected to the mains voltage and when it is in operation. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Galvanic isolation from the mains phase using a fixed or variable transformer is always recommended. Figure 1 shows the symbols that identify the isolated and non-isolated devices.

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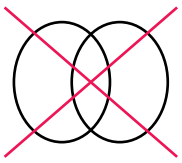

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a. Isolated

b. Not isolated

Fig 1. Variable transformer (variac) isolation symbols

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3. Specifications

Table 1 contains the SSL5015DB1201 demo board specifications.

Table 1. SSL5015DB1201 specifications

Symbol	Parameter	Value
V_{mains}	AC mains supply voltage	120 V
V_{LED}	output voltage	60 V
I_{LED}	output current	260 mA
$\Delta I_{LED}/\Delta V_{LED}$	output voltage rejection	3 mA/15 V
η	efficiency	> 87 %
PF	Power Factor	0.96
THD	Total Harmonic Distortion	< 30 %
T_{oper}	operating temperature	-40 °C to +100 °C
f_{sw}	switching frequency	70 kHz
$I_{o(ripple)}$	ripple output current	7 % (16 mA)[1]

[1] The ripple current can be reduced by using a larger bus capacitor or output capacitor. For example, with a 100 μF capacitor at output, the ripple current can be reduced around 5 % at rated voltage input.

Figure 2 shows the dimensions of the SSL5015DB1201 demo board.

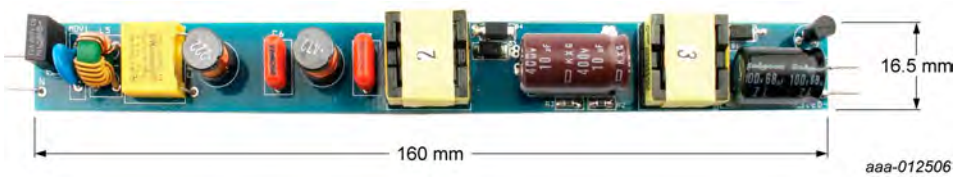

Fig 2. SSL5015DB1201 board dimensions

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4. Board photographs

a. Top view

b. Bottom view

Fig 3. SSL5015 18 W demo board

5. Board connections

The board is optimized for a 120 V (60 Hz) mains supply. In addition to the mains voltage optimization, the board is designed to work with multiple LEDs or an LED module with a high forward voltage.

Remark: The maximum rated voltage of the board is 132 V (AC).

The anode of the LED load is connected to the LED+ connector. The cathode is connected to the LED− connector. Use an LED string forward voltage of up to 60 V on this demo board. Under the expected operating conditions, the output current is 260 mA.

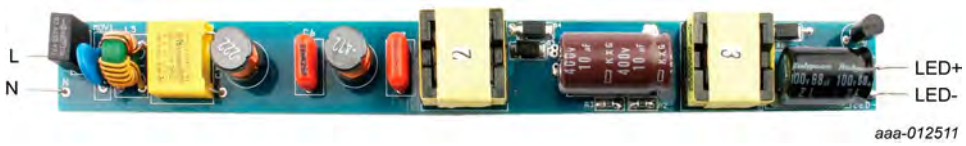

Fig 4. SSL5015DB1201 board connections

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6. Functional description

In this application, the SSL5015 is used in a double stage boost-buck topology instead of in the designated buck topology for two reasons:

- With a boost stage at the input side, the input capacitance of the system can be kept to a minimum, allowing a high power factor.
- With a buck stage at output side, the output ripple can be low because the bus voltage supplied by the preceding boost stage is stable.

When using the boost-buck application, only one switching FET is required to draw current through the boost and buck stages. The switching current in both stages flows through the same switching FET.

The IC senses the current through the sense resistor (R6; R13) and switches off when it reaches the peak value. Most of the current in the sense resistor flows mainly through the output LEDs. The boost current follows a different return path through resistor R8. It only slightly effects the peak current through the sense resistors. So, the output current can be calculated in the same way as with an SSL5015 buck converter.

6.1 PF and THD performance

The SSL5015DB1201 demo board is designed for high power factor operation (PF > 0.95 at 120 V (AC)) and low THD performance (THD < 30 % at 120 V (AC)). The return current of the boost stage shapes the input current waveform. So, PF and THD depend on the ratio between the boost inductor (L2) and the buck inductor (L3). A ratio of L2/L3 that is smaller generally provides a higher PF and a lower THD. However, it also causes a higher bus voltage which challenges the IC voltage rating. So, keep the inductor value accuracy of both within 5 %.

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7. Performance

7.1 Efficiency

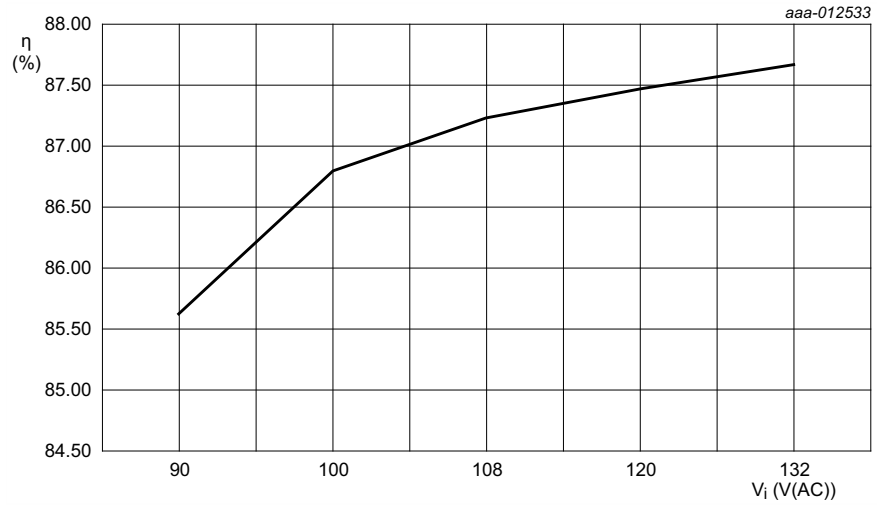

Fig 5. Efficiency as a function of mains input voltage (AC)

7.2 Power factor

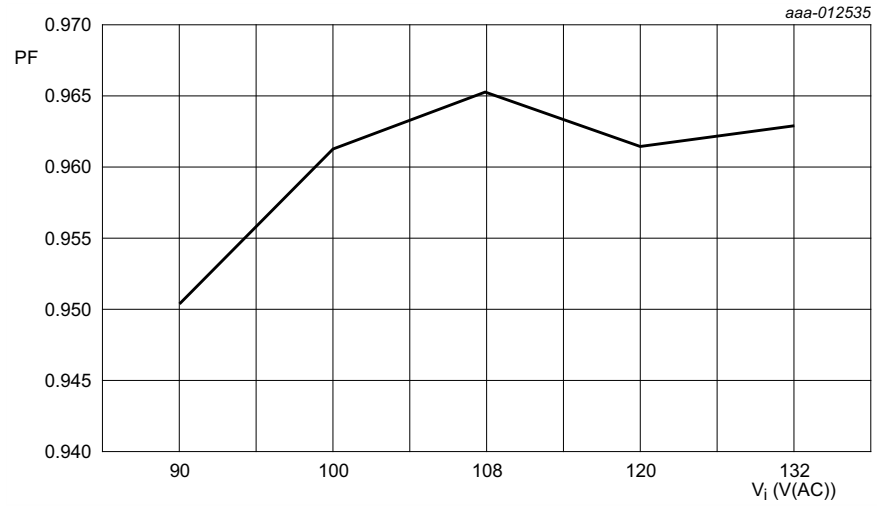

Fig 6. Power factor as a function of mains input voltage (AC)

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7.3 Line regulation

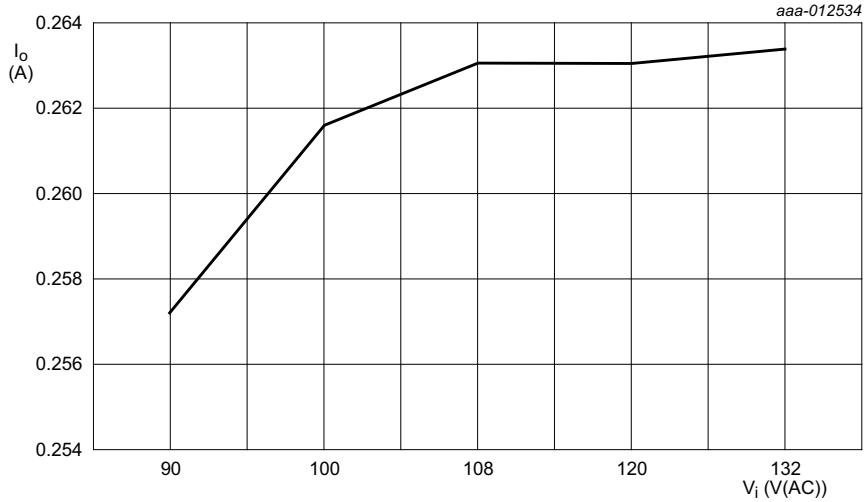

Fig 7. Output current as a function of mains input voltage (AC)

7.4 Load regulation

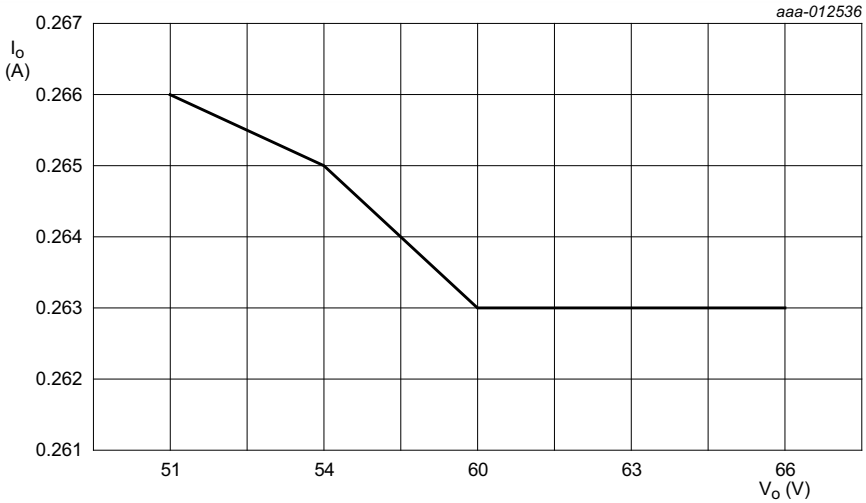

Fig 8. Output current as a function of output voltage

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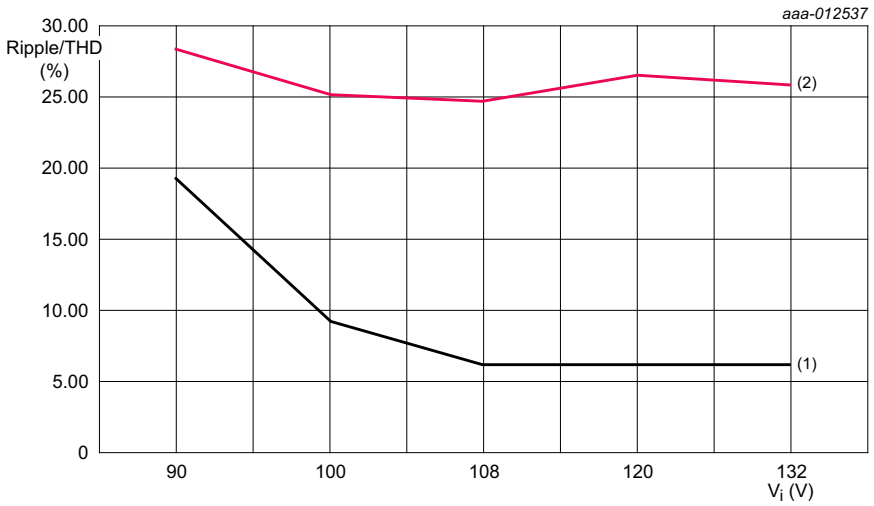
7.5 Ripple and THD



(1) Output ripple

(2) Input THD

Fig 9. Output ripple and input THD as a function of input voltage

Remark: To increase the bus voltage, reduce the L2 (boost inductance) / L3 (buck inductance) ratio. The reduction ensures better output ripple performance in 100 V (AC) applications.

7.6 ElectroMagnetic Interference (EMI)

EMI was measured according to the EN55015 standard. The SSL5015DB1201 demo board complies with the requirements of the standard (see Figure 10 to Figure 12).

The SSL5015 series operates as a boundary conduction mode converter. A special feature, called valley detection, is an integrated part of the SSL5015 series circuitry. Dedicated built-in circuitry connected to the DRAIN pin senses when the voltage on the drain of the switch has reached its lowest value. This feature reduces switching losses. It also greatly benefits the EMI performance of the LED driver.

The switching point follows immediately after the buck stage. Both inductors in this circuit are sensitive to other magnets. So, to optimize the EMI performance, an outer shielding has been added on both inductors. This shielding ensures better EMI performance over frequency ranges are > 300 kHz.

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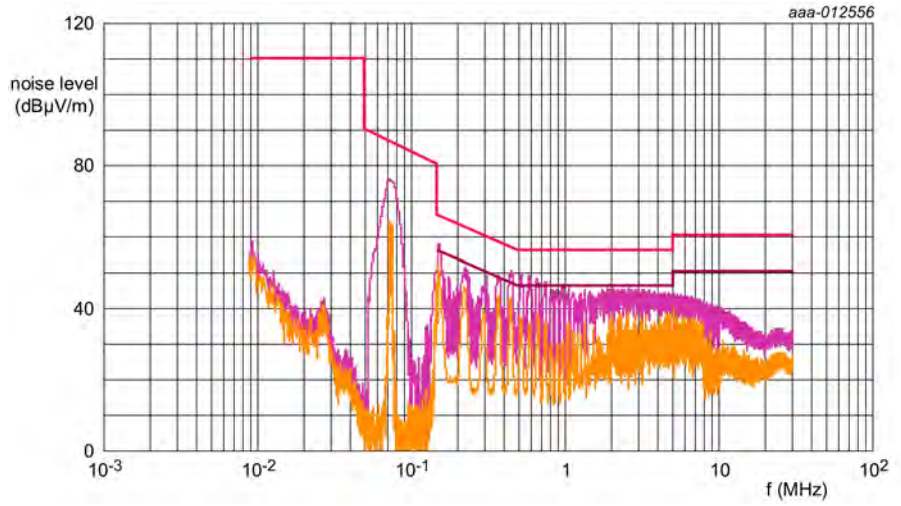

Fig 10. EMI performance - Conduction Emission (CE) - L-phase

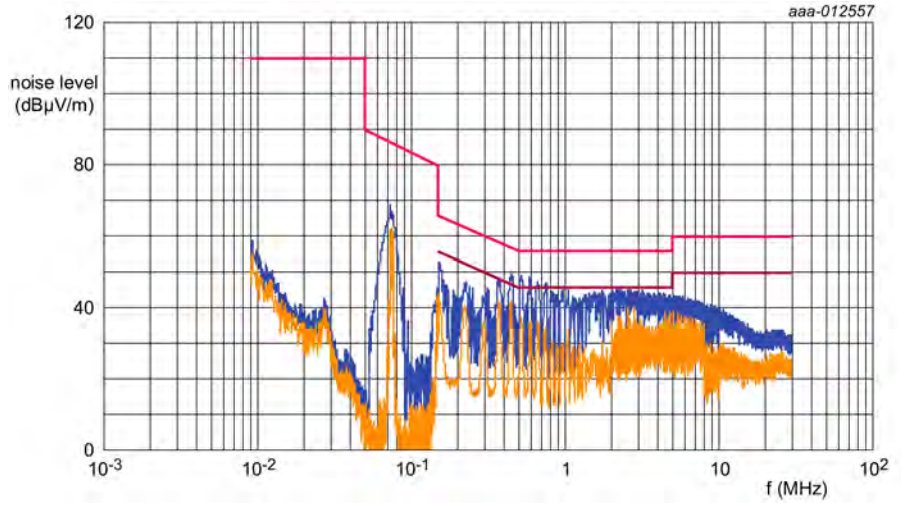

Fig 11. EMI performance - Conduction Emission (CE) - N-phase

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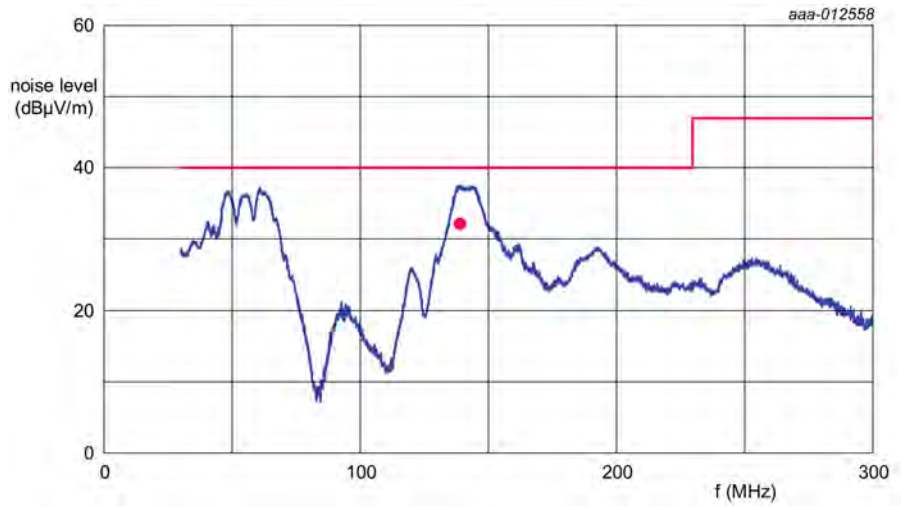

Fig 12. EMI performance - Radiation Emission (SE)

8. Protections

8.1 Bus OverVoltage Protection (OVP)

Additional protections are embedded to provide input overvoltage protection (R2; R3; R4; R5; ZD1; Q2) for the boost stage (see Figure 13). The input overvoltage protection switches off the IC when the bus voltage on C1 is too high. If the bus voltage exceeds the OVP set point (= 282 V), it pulls down the VCC voltage. The limit can be tuned by adjusting the ratio between R2, R3 and R4. The limit must be tuned below the maximum voltage rating of the IC. The protection automatically restarts when the input voltage is reduced.

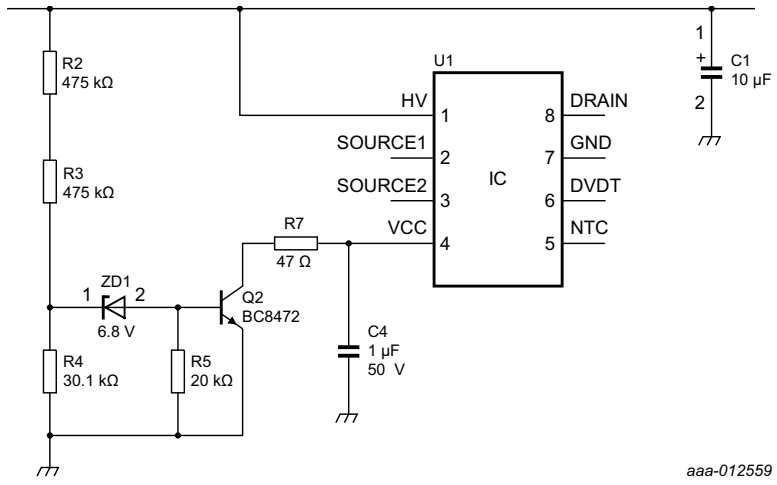

Fig 13. Bus overvoltage protection

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8.2 Boost OverCurrent Protection (OCP)

If the boost peak current exceeds V_{th} / R8 (V_{th} is the threshold voltage of Q3 and D7; see Figure 14), the overcurrent protection in the boost stage (R8; Q3; D7) pulls down the VCC voltage.

This circuit is not active under typical conditions. However, the circuit is required because the IC cannot detect boost stage peak currents in this topology.

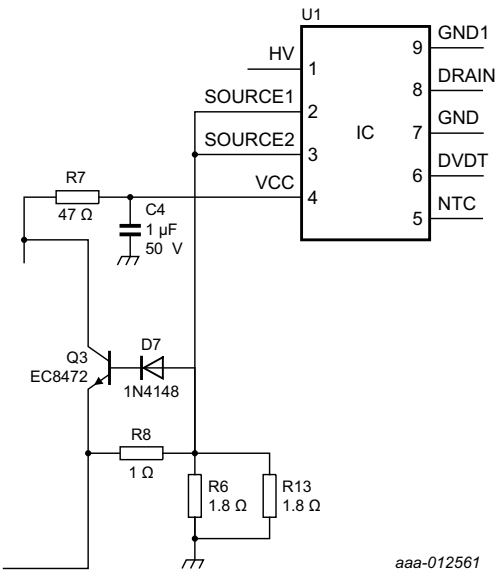

Fig 14. Boost overcurrent protection

8.3 Output OverVoltage Protection (OVP)

The voltage rating of the output capacitor can be limited to 100 V. However, extra components (ZD2; Q4; R11; R12) are then required to protect the output capacitor against possible high voltages (see Figure 15).

The circuit provides a low impedance path if the output voltage exceeds the breakdown voltage of Zener diode ZD2. The IC detects this low impedance as a short at the output and activates the output short protection (latched protection).

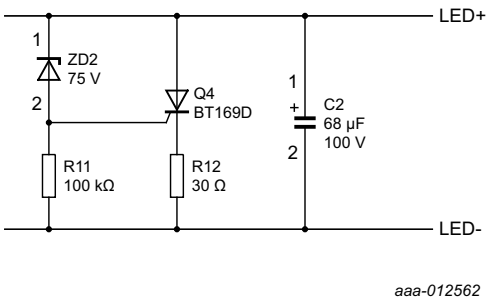

Fig 15. Output overvoltage protection

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9. Schematic

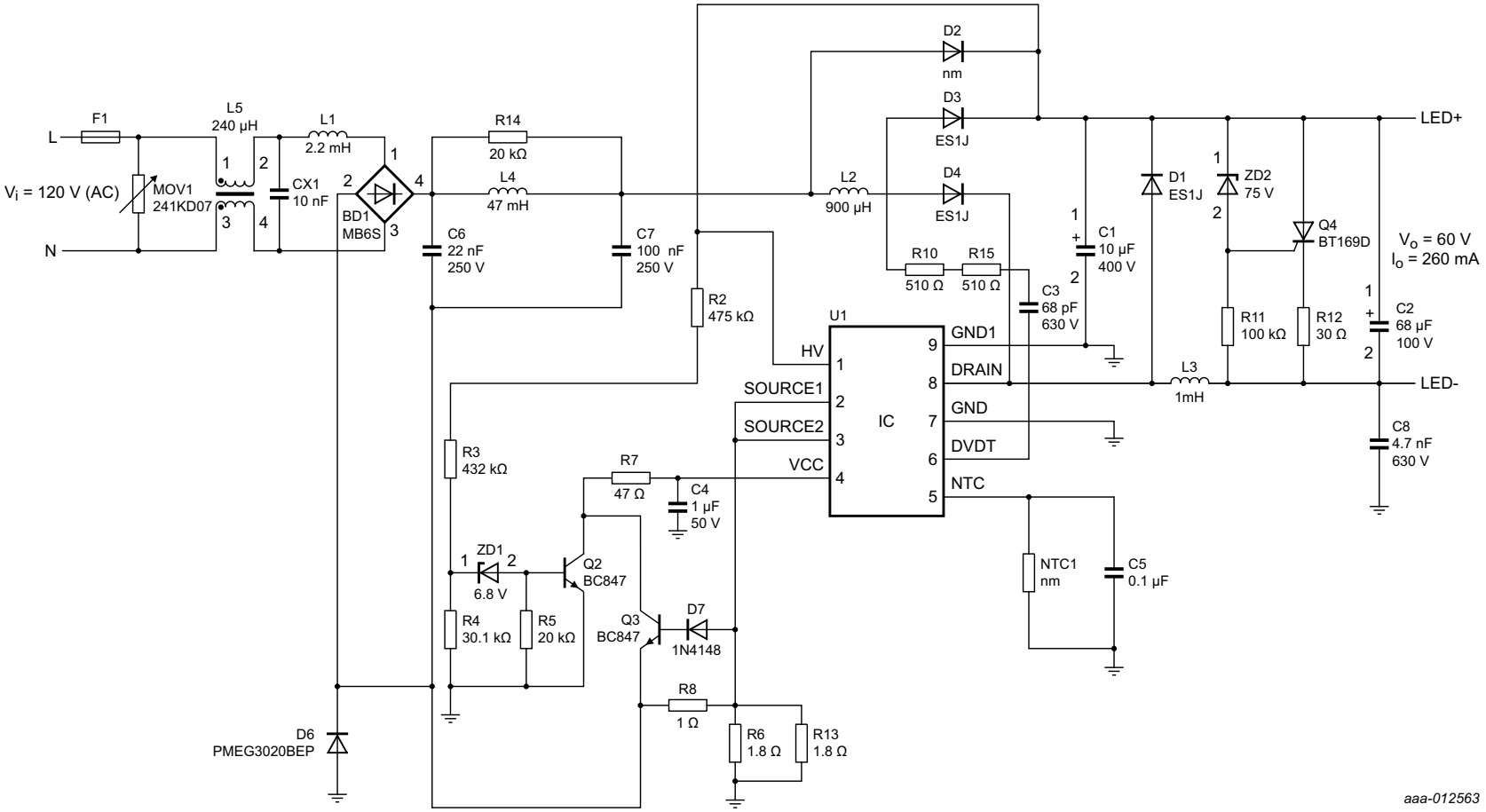

Fig 16. 120 V 18 W TLED LTHD_LR dual stage converter with SSL5015DB1201 demo board schematic

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10. Bill Of Materials (BOM)

Table 2. SSL5015DB1201 bill of materials

Reference	Description and values	Part number	Manufacturer
BD1	bridge rectifier	MB6S	-
CX1	X-capacitor; 10 nF; pitch = 10 mm	-	-
C1	capacitor; 10 μF; 400 V; pitch = 5 mm; 10 × 20 mm	-	NCC
C2	capacitor; 68 μF; 100 V; pitch =5 mm; 10 × 16 mm	-	Rubycon
C3	capacitor; 68 pF; 630 V; 1206	GRM31A7U3A680JW31D	Murata
C4	capacitor; 1 μF; 50 V; 0805	-	-
C5	capacitor; 0.1 μF; 25 V; 0603	-	-
C6	capacitor; 22 nF; 250 V; pitch = 7.5 mm	-	-
C7	capacitor; 100 nF; 250 V; pitch = 7.5 mm	-	-
C8	capacitor; 4.7 nF; 630 V; 1206	GRM31BR72J472KW01L	Murata
D1; D3; D4	diode; ES1J; SMA	-	-
D6	diode; SOD128	PMEG3020BEP	NXP Semiconductors
D7	diode; SOD323	1N4148	-
F1	fuse; 250 V (AC); 1 A; pitch = 5 mm	-	-
L1	inductor; 2.2 mH; I_{sat} = 0.35 A; 8 × 10 mm	744 772 022 2	Würth Elektronik
L2	inductor; 900 μH; 5 %; EFD15	-	-
L3	inductor; 1 mH; 5 %; EFD15	-	-
L4	inductor; 4.7 mH; I_{sat} = 0.25 A; 8 × 10 mm	744 772 472	Würth Elektronik
L5	inductor; 240 μH; 7Ts; T8 × 4.2 × 3.8 mm	-	-
MOV1	varistor; 241KD07	-	-
Q2; Q3	transistor; SOT23_123	BC847	NXP Semiconductors
Q4	thryristor; TO92	BT169D	NXP Semiconductors
R2	resistor; 475 kΩ; 1 %; 1206	-	-
R3	resistor; 432 kΩ; 1 %; 1206	-	-
R4	resistor; 30.1 kΩ; 1 %; 0603	-	-
R5	resistor; 20 kΩ; 1 %; 0603	-	-
R6; R13	resistor; 1.8 Ω; 1 %; 0805	-	-
R7	resistor; 47 Ω; 5 %; 0603	-	-
R8	resistor; 1 Ω; 1 %; 1206	-	-
R10; R15	resistor; 510 Ω; 5 %; 1206	-	-
R11	resistor; 100 kΩ; 5 %; 0805	-	-
R12	resistor; 30 Ω; 1 W; 5 %; 2512	-	-
R14	resistor; 20 kΩ; 5 %; 1206	-	-
U1	IC; SSL5015TE; HS08	SSL5015TE	NXP Semiconductors
ZD1	Zener diode; SOD323	BZX384-B6V8	NXP Semiconductors
ZD2	Zener diode; SOD323	BZX384-C75	NXP Semiconductors

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11. Board layout

a. Top view

b. Bottom view

Fig 17. 120 V 18 W TLED LTHD low ripple dual stage converter with SSL5015DB1201 demo board layout

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12. Inductor specification

12.1 L2 boost inductor

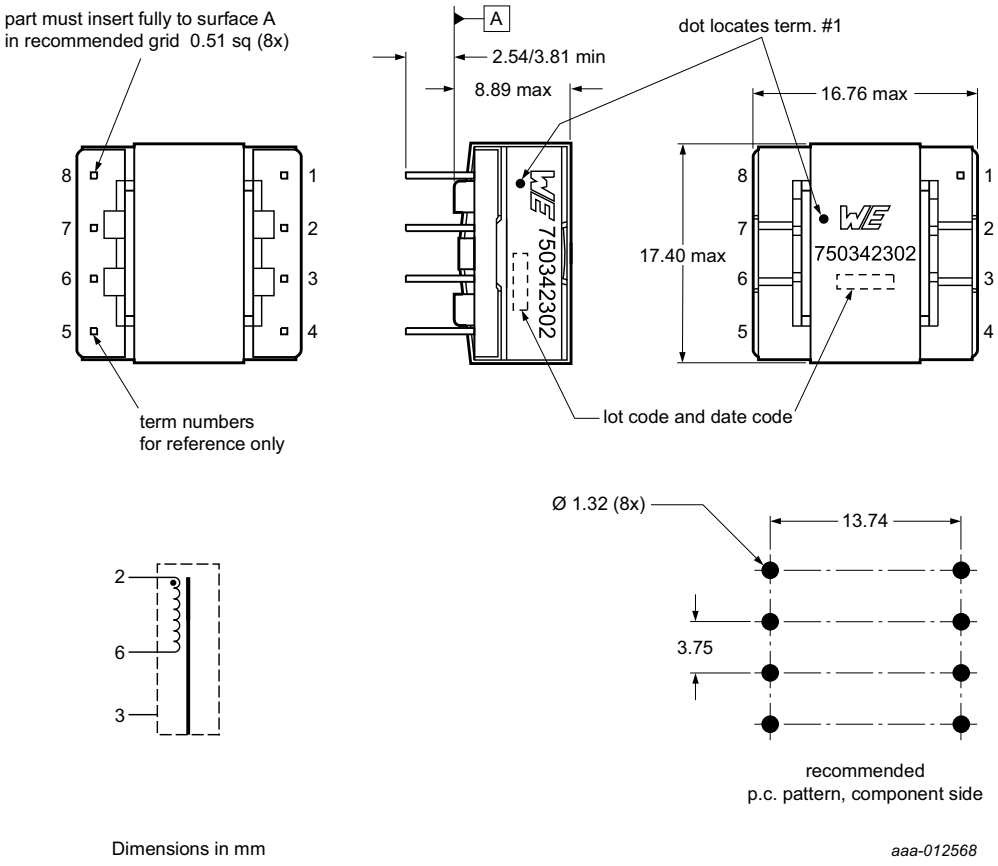

Fig 18. Boost inductor layout and dimensions

Table 3. L2 boost inductor specifications

Parameter	Value	Test conditions
Electrical specifications		
DC resistance 2-6	maximum 1.327 Ω	at 20 °C
inductance 2-6	0.9 mH ±5 %	50 kHz; 100 mV (AC); 1 s
General specifications		
operating temperature range	–40 °C to +125 °C	incl. temperature increase

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12.2 L3 buck inductor

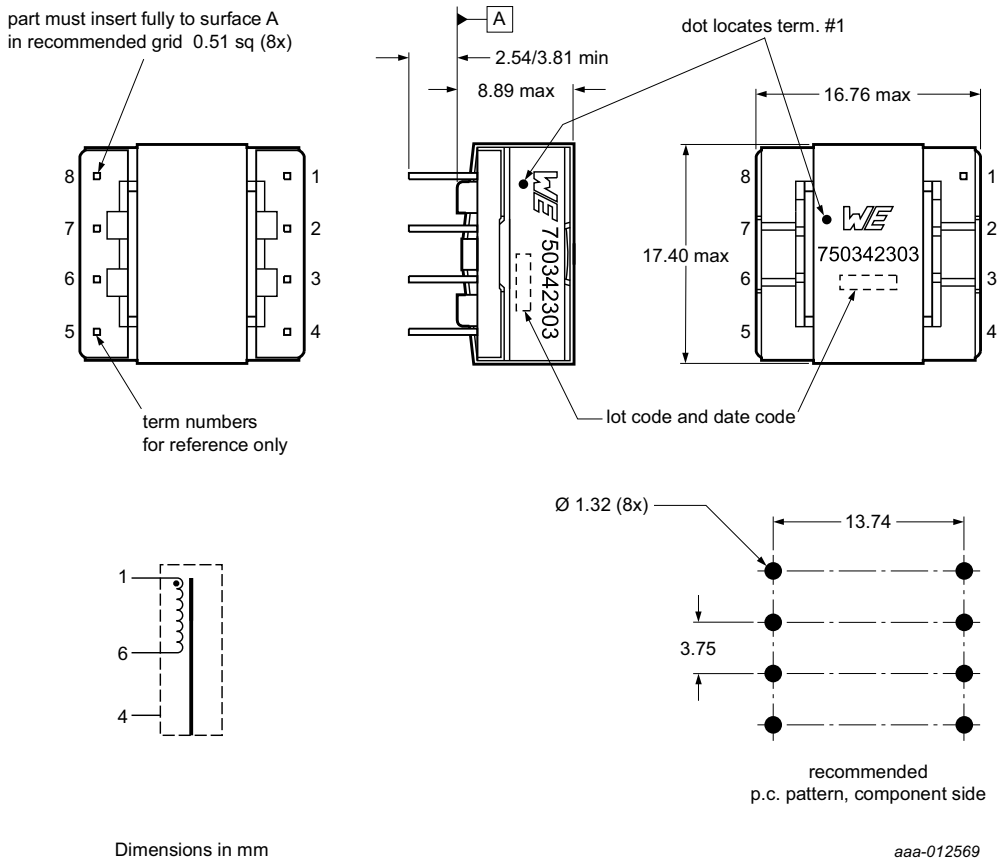

Fig 19. Buck inductor layout and dimensions

Table 4. L3 buck inductor specifications

Parameter	Value	Test conditions
Electrical specifications		
DC resistance 1-6	maximum 1.221 Ω	at 20 °C
inductance 1-6	1.0 mH ±5 %	50 kHz; 100 mV (AC); 1 s
General specifications		
operating temperature range	–40 °C to +125 °C	incl. temperature increase

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For sales office addresses, please send an email to: salesaddresses@nxp.com

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